

Helios Mission Support

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Helios-1 spacecraft has now completed its first perihelion passage of the Sun. This article covers the DSN support to Helios-1 from its passage in front of the Sun (inferior conjunction) through its first perihelion passage, with particular emphasis upon the quantity and quality of the DSN support.

I. Introduction

This is the third article in a recent series pertaining to the Helios-1 flight support that has been provided by the DSN. The previous article (Ref. 1) discussed the Helios Mission Phase I/II handover and the changes in operational interfaces between the DSN and German Flight Operations Teams after Project Operations Control returned to the German Space Operations Center (GSOC) from JPL. A spacecraft high-gain antenna signal variation anomaly, with its attendant impact upon the committed Helios-1 tracking schedule, was also described. The DSN System Performance and tracking coverage reported in that article closed as Helios-1 was completing its first inferior conjunction. This article continues from the latter event up through completion of the first Helios-1 perihelion passage.

II. Helios Mission Status and Operations

A. Helios-1 Inferior Conjunction

Helios inferior conjunction offered the DSN an extraordinary performance calibration point, prior to the first Helios-1 superior conjunction. Helios-1 inferior conjunction occurred from February 16 through 22, 1975. This time period is in respect to the time that the Sun-Earth-Probe (SEP) angle was five degrees or less. On February 18, 1975, Helios-1 crossed in front of the Sun's photosphere, at which time a total telemetry blackout occurred.

The inferior conjunction data collection objective was twofold. The first objective was to improve the data collection procedures and to verify that sufficient data would be available to perform the desired analysis during

superior conjunction. The second objective was to compile a reliable data base so as to generate predicts on the excessive system noise temperature (SNT) versus the SEP angle, and to also predict the SEP angle versus the system noise temperature ratio residuals.

Both objectives were met and subsequently applied to a Pioneer superior conjunction with predicted results, but the Pioneer SEP angle was 1.8 degrees, whereas Helios-1 will have an SEP angle of less than 0.5 degrees from May 2 to 13, 1975. The solar noise effects upon the telecommunications link are expected to increase dramatically during this period. These data will then be used to provide improved predictions of expected noise, improved data monitoring, and considerations for future mission planning.

B. Helios-1 Perihelion

On March 15, 1975, at 0912:14.7, Universal Time, Helios-1 reached its first perihelion at 0.3094343 AU. The performance of all spacecraft and DSN subsystems was excellent throughout the perihelion period.

The perihelion, which occurred 96 days after launch, was the focal point of scientific interest, but a 25-day period surrounding perihelion encompassed the expanded region of scientific interest. During this period of high scientific interest, the spacecraft traversed an unexplored region of inner solar system space. The results of Helios-1 perihelion objectives, which are to study the properties of the Sun's influence on Earth, are still being analyzed. The DSN objective to provide continuous coverage and achieve optimum performance in order to maximize the return of scientific data in both quantity and quality was met.

Optimizing the performance of the Deep Space Stations (DSSs 12, 14, 42, 43, 44, and 62) supporting Helios during this special coverage period was the major thrust of the planning and scheduling effort. Special pre-pass readiness tests for each prime and backup station were conducted throughout the perihelion period. Full redundancy of station coverage was not practical during this, the major phase of the Helios-1 mission, due to the significant requirements also placed on the DSN by the Mariner and Pioneer Projects during March 1975. The scheduling of backup stations to provide coverage was planned and did occur when the Mariner Project declared a spacecraft emergency on March 13, 1975. This required 64-meter antenna coverage to ensure that the Mariner 10 spacecraft was in a stable attitude prior to its third encounter of Mercury on March 16, 1975, which was one day after Helios-1 perihelion. All perihelion commitments were met by all elements of the DSN, and the perihelion phase activities were quickly supplemented by those activities relating to superior conjunction.

C. Helios-1 Superior Conjunction Plan

As Helios-1 sped through the perihelion region and successfully fulfilled its science criteria from that region of unexplored space, new scientific objectives came into focus as it approached superior conjunction. The primary emphasis during the first Helios superior conjunction is the accumulation of science data for the Faraday rotation and celestial mechanics experiments.

The Helios-1 superior conjunction has two periods of interest. The first period of interest is for the Radio Frequency Analytical Study by the DSN. The second is the Project period of interest. The dates of the defined period of DSN analytical and Project scientific studies, encompassing the first Helios-1 superior conjunction, are from April 7 to June 24, and April 13 to June 8, 1975, respectively. This conjunction will not result in a complete spacecraft occultation by the Sun, but the SEP angle will sweep across within 0.43 degrees of the Sun's photosphere.

The period of DSN analytical interest is when Helios-1 is within plus and minus 5 degrees of the SEP angle.

The highest period of scientific interest is when Helios-1 is within plus and minus 3 degrees of the SEP angle. The dates and degrees of SEP angle are as follows:

SEP, deg	Entry date	Exit date
5	4/7/75	6/24/75
4	4/10/75	6/16/75
3	4/13/75	6/8/75
2	4/18/75	5/29/75
1	4/24/75	5/20/75
0	5/2/75	5/13/75

1. **Faraday rotation.** As Helios-1 approaches the solar disk proximity, telecommunications with the spacecraft will be nearly impossible, if not totally blacked out by solar-generated noise. At this time, the Faraday rotation experiment will be within its region of critical interest. In conjunction with the Faraday rotation data accumulation, the DSN will also analyze spectral broadening of the spacecraft's radio frequency (RF) link and the observed quadripod effects in conjunction with the increased system noise temperatures at DSS 14.

DSS 14 is the experimenter's prime station for retrieving the Faraday rotation data. Weather data and

system noise temperature data are gathered from around the Network. DSS 14 supports weather data, automatic polarimeter tracking data in both the correlation and phase lock modes, and open-loop receiver data during periods of non-coherent operations. The experimenter will provide his Helios-B requirements to the Project Office later this year. The Helios-B requirements will be derived from the knowledge obtained from the results of the analysis of Helios-1 data reduction.

2. Celestial mechanics. The celestial mechanics experiment employs the Helios-1 radio metric data obtained during real-time tracking of the spacecraft to derive information regarding the Sun and its planet's ephemeris. Further, as the spacecraft's radio signal passes close to the Sun while enroute to Earth, possible bending effects due to the Sun's gravity may be noted. Such effects, predicted by Einstein, would be most noticeable as an increased range measurement caused by the longer (i.e., bent) path taken. Such an effect would have a magnitude of approximately 200 *microseconds* out of a total round-trip time of 1/2 hour. The measurement of such a small quantity requires extreme care and precision by the DSN. Further, this measurement will be made in the presence of an extremely large noise level due to the effects of the solar corona. This is, therefore, the challenge to be met during the Helios-1 solar occultation (blackout) period.

D. Actual Versus Scheduled Tracking Coverage

This tracking coverage report, encompassing the time period between February 10 and April 14, 1975, spans two important periods of the Helios-1 scientific mission phase. The two major Helios-1 events that occurred during this time were inferior conjunction and perihelion. In addition to Helios perihelion, there were also increased Mariner 10 and Pioneer 10/11 activities that occurred simultaneously.

The DSN commitment to provide continuous tracking coverage throughout this phase of the Helios Mission was met. A total of 168 tracks had been scheduled at DSSs 12, 14, 42, 43, and 62. The number of actual tracks supported during this time frame was 172. This included demonstration passes at DSSs 43 and 44 and two extra tracks at DSS 12. One of the extra tracks at DSS 12 was to provide backup commanding when DSS 14 incurred Command System problems, which will be discussed later in this report. The second additional track at DSS 12 occurred when a Mariner 10 spacecraft emergency was declared. DSS 14, which was supporting Helios at the time of the emergency, was then required to support Mariner 10. DSS 12 was called up to support Helios in real-time, this resulting in Helios data outage of approximately 20 minutes.

The long-range schedule, which had not included plans for a third Mariner 10 encounter of Mercury, had projected 64-meter station coverage throughout the 25 days of perihelion coverage. The added requirement to support a third Mercury encounter would result in a loss of 64-meter station coverage to the Helios perihelion coverage. When it was ascertained that there would be a third encounter, four Helios 64-meter tracks were given over to Mariner, through negotiations, to ensure a successful finale to the Mariner Project. In total, only six 64-meter station tracks were lost to Mariner 10.

On March 24, 1975, Pioneer 11 had a superior conjunction, and Pioneers 10 and 11 were also in a spiral alignment at the same time. During this period, which was equally important to the Pioneer Project, several tracking passes at 64-meter stations were shared.

The sharing of resources during March to optimize tracking coverage resulted not only in the DSN meeting the Helios-1 commitments, but also successfully culminated in the highly active Helios, Mariner, and Pioneer Project events being met during March 1975.

III. DSN System Performance for Helios

A. Telemetry System

The Helios Telemetry System performance during the months of February and March 1975 continued to follow the predicted levels of performance, which had been the case since launch, with only minor variations. In the time span from launch through January 1975, the telecommunications link performance had exceeded the predicted performance levels. The performance trend in February averaged out to slightly below the predicted level. The March performance returned to the previous level, while the incongruities of February remain unexplained. It should be noted, however, that the above variations in performance basically lie within the pre-flight uncertainty tolerance and only infrequently exceed the predicted margin of tolerance.

While there was no single incident of significance reported as a telemetry failure, there were two categories of discrepancy reports (DRs) that contributed to almost 50% of the total reported failures within the Telemetry System. These two categories are Data Decoder Assembly (DDA) failures and Automatic Total Recall System (ATRS) failures.

The DDA failures have historically been the prime contributor to the total number of DRs, but in the past two months, ATRS discrepancy reports have attributed to

approximately 20% of all DRs. These two categories of DRs have received special attention from the DSN Operations Analysis Group.

During March 1975, the Block IV receiver at DSS 14 became operational. The analysis of the Helios link performance, based on the usage of the Block IV receivers, has not been satisfactorily validated due to insufficient evaluation time.

The DSN Operations Analysis Group continues to monitor the spacecraft's performance on medium-gain and high-gain antenna operations. The spacecraft's performance, compared to predictions, appears to be slightly better on the medium-gain antenna. This could be due to the signal level variations that have been observed on the high-gain antenna, as reported in the previous article. It has not been ascertained at this time that these variations occur only during high-gain antenna operations, but the magnitude and the effects on performance have not been detected during medium-gain antenna operations.

B. Tracking System

The DSN Tracking System performance for Helios through March 1975 has continued to be nominal. The spacecraft was tracked a total of 178 times during this reporting period. The trend analysis of doppler noise and two-way doppler residuals has not revealed any deviations away from the predicted performance. There were no significant Helios tracking discrepancy reports opened during this period.

C. Command System

The total Helios DSN-supported command activity, from launch through March 1975, has totaled 12,503 commands. The cumulative command aborts during this period of support were six. Four aborts were termed Project aborts, when a command is aborted remotely by Project, and two were system aborts. A system abort is the result of a Deep Space Station Command System failure.

The two system aborts both occurred at DSS 14 during March 1975. In addition to the two aborts, more than seven hours of station command capability were lost before the problem could be isolated. The seven hours of lost command capability are an accumulated total from nine different tracking periods.

The problem was, in fact, two problems within the Command Modulation Assembly (CMA). The combination of the two problems produced intermittent anomalous

conditions; this contributed to the lengthy delay of its isolation. Initially, what appeared to be software-oriented, and later proved to be hardware problems, also caused delays in isolation. With the hardware corrections, a new preventive maintenance procedure will also provide an increase in the level of command reliability.

DSS 43 also encountered hardware problems that resulted in a loss of command capability during periods of inclement weather. Heavy rainfall resulted in excessive levels of reflected transmitter power within the antenna microwave system, which caused the transmitter to automatically shut down. The excessive reflected power will be corrected by replacing a section of mismatched waveguide on the diplexer. Until the waveguide is replaced, the transmitter is operated at only 5 kW.

The only other significant Command System anomaly occurred at DSS 42. Project commanding was delayed 180 minutes when numerous subcarrier frequency alarms were received. A subsequent investigation revealed that installation of a new equipment rack next to the Frequency and Timing Subsystem (FTS), on a non-interference basis with Helios tracking, probably resulted in a spurious malfunction of the FTS Subsystem. The command activity was such that commanding could be delayed until DSS 62 had acquired and was in a green command posture.

IV. Conclusions

The Helios-1 spacecraft has now completed its first inferior conjunction and perihelion passages. Helios-1 has also met its prescribed initial scientific objectives, with all 10 of its experiments remaining active. As the spacecraft continues in its orbit around the Sun and its first superior conjunction occurs, the passive experiments (celestial mechanics and Faraday rotation) become the prime scientific experiments. During the reporting period of this article, the scheduling of DSN resources by all current flight projects was especially high. With the occurrence of superior conjunction, the Helios-1 spacecraft will have completed its Phase II mission milestones. The Helios-1 Mission Phase III support requirements will result in reduced level of Project support activities from the DSN.

The 11th Joint Working Group Meeting has been scheduled for the latter part of May 1975. This meeting will emphasize the Helios-B launch preparation activities. Helios-B activities will then be on an ever-increasing scale throughout the remaining portion of the year. Thus, the reduced Helios-1 support will be offset by increasing Helios-B activity. These and related topics will be treated in future issues of this report.

Reference

1. Goodwin, P. S., "Helios Mission Support," in *The Deep Space Network Progress Report 42-26*, pp. 22-26, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1975.